NAVAL POSTGRADUATE SCHOOL

Monterey, California

AN INTEGRATED PRODUCTION FUNCTION

FOR A MILITARY HMO

by

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and

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A mathematical model of an operational military Health Maintenance Organization is constructed integrating both inpatient and ambulatory care outputs. Incorporating the interdependencies in staffing and facilities utilization, the model holds promise for extension to civilian HMO's with parametric changes in methods of practice. The model may be used descriptively to indicate maximal patient care levels in specific patient categories (i.e., the derivation of the "production

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20. possibilities frontier for health care) and to identify bottleneck constraints. As an optimization tool, budgetary allocation decisions are facilitated in both the long and short run, in terms of maximizing patient flow and minimizing the cost of providing for a given eligible population, respectively.

I. INTRODUCTION.

The military health care delivery system is under close scrutiny from within and without. The cost and quality of its product are subjects of significant research projects. This stems from the increasing concern in the federal budgetary review process with the cost of operating the network of Regional Medical Centers (RMC) and satellite dispensaries as well as the cost of the CHAMPUS program.

The quality and accessibility of care are freshly emphasized concerns due in large part ot the recruiting needs associated with the All Volunteer Force.

The loss of the physician draft and accompanying dependence on "the market" for replacements makes the efficient use of M.D. services imperative.

The derived cuts in both operations and capital budgets at the field facility level has caused heightened awareness of the utility and necessity for local resource allocation information and algorithms.

The purpose of this paper is to begin to construct an analytical model of the production process of a military RMC (in reality more a health maintenance organization (HMO) than just a hospital) which when refined and validated, could be used both by local personnel to achieve a greater output with its fixed resources and by the more centralized budget planners to determine the best allocation of scarce dollars over the competing institutions.

Optimally one would like a model of the military HMO to be capable of answering (or contributing to the answer to) questions such as, "if we reduce retired, or retired and their dependents, or all but active duty care to zero, what will be the effect on the cost of operation of a specific facility.

This involves a model which is able to handle the fact that these different groups have differential historical utilization patterns and hence potentially great differential impact on the cost reductions associated with their implementation.

In addition, we would want to be able in many cases to "cost this out" on a area basis, given the existence of relatively new facilities in some places and older ones in others with associated differential fixed costs.

In short, a model at a disaggregated level which accurately portrays the local production process and is capable of being applied (with modifications) to other areas and of being used in aggregation calculations as well is a very desirable end product.

The model which we present in section III below is a first step in this direction. It is the result of coordination with the personnel and observation of the operation of the Naval RMC at Oakland, California.* We have attempted to "integrate" the fact that the production process includes both inpatient and ambulatory care into the model in a non-trivial way, an effort which we see as a necessary condition to its utility.

There are two segments of the literature which are pertinent to the present study: That of the existing analytical models of hospitals and the hospital "Cost Function" papers.

Considering the latter first, Lee and Wallace [10] have identified some of the problems in using econometric techniques to derive hospital cost functions. They include the fact that since hospitals are in reality multiproduct firms, products are not clearly distinguishable, separate accounting data on costs, inputs and outputs by specific type are not available, the assumption of cost minimization upon which derivation of cost functions rests may not hold in not-for-profit institutions, and final products of one department are often intermediate products for others such that there exist substantial flows across product lines,

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*We are grateful to Admiral Faucett and his staff for their cooperation, and especially to LT Joe Steiner. This paper however, should in no way be construed as having their endorsement. The on-site research was conducted as part of Mr. Van Winkle's masters thesis project and involved a six week residency at the facility.

All of which make derivation of cost functions difficult and suspect. They in fact address themselves only to an examination of the relationship between variation in case-mix and average costs.

Lave and Lave [8] also concentrate on explaining changes in costs and note that explanation of the level of absolute costs needs further work. They cite as major problems in attempts to utilize estimated cost functions in hospital research (such as prospective reimbursement) that:

(i) They are really only approximations over relevant ranges and not true costs;

(ii) The estimated marginal costs are sensitive to functional specification;

(iii) There is a lack of a good measure of output;

(iv) The quality of the same type of service varies over hospitals.*

Feldstein [5] in his now classic study points out the same range of problems with cost functions.

Included in the list of obstacles to the utility of the cost function approach in HMO cases has been the emphasis on inpatient care to the almost total neglect of the ambulatory side. Pointer et.al. [15] constructed a cost function in a Naval RMC setting for an outpatient care department and Kovner [7] did so for a Kaiser facility. However there does not exist, to the author's knowledge, a joint cost function.

We move then to the literature dealing directly with production models. The model closest in structure and apparent intent to that we propose in this paper presently available in the literature seems to be that of Baligh and Laughhunn [1]. They develop the idea of equivalence classes of patients in order to address the output measure problem and define the resources or inputs necessary to treat

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*This is very much of a problem in prospective reimbursement schemes. Use of constructions such as hospital cost indices (see [3], [13], and [17]) require that quality and case mix manipulation be reflected in the index value. See [2] for a critique and a proposed solution.

members of each class in much the same way as is done in this paper. However there are at least two major differences in our model. First, we deal with these two problems on a much less aggregated level so that the model will offer the administrations greater flexibility. Second, we consider both inpatient and out-patient categories. Their model however, did provide insights and guidance in the construction of that presented in section III.

Dusansky and Kalman [4] in a recent paper attempt to deal with the teaching aspect of accurately modelling the operation of a hospital and the dynamics of patient flow through categories associated with the hospitals teaching function. They assume full capacity utilization and specify the cost function as their objective function. The model however, is too general to assist in institutional resource allocation decisions. Their general model (special case) of a non-teaching hospital does not, for example, relate the derivation of optimum length of stay to the cure of the disease or condition. We attempt in the present model to address the teaching role of the military HMO as it effects the production process.*

*The reader should consult Reinhardt's recent paper [16] for a good summary of the scope and types of models which have appeared in the literature.

II. USE OF SHADOW PRICING

The military hospital has, in some ways, the same sort of problem as found in the not-for-profit hospital. In both cases neither the objective function nor its elements are well defined. Various authors (see, for example [9], [12]and[14]) have suggested that these NFP institutions maximize combinations of outputs and its quality or that they (the hospitals) are used by the physicians on the hospital's panel to maximize individual incomes by being utilized as a workshop, etc.

The military facility has an additional problem however in that there are no direct patient or fiscal intermediary charges (and hence revenues) associated with the operation of its various components. This complicates the internal resource allocation process because of the resulting lack of monetary proxy measures of net benefits which normally accrue as a result of parametric changes in the mode of the hospital's operation.

To illustrate, suppose a NFP hospital has an objective function $\emptyset$ which depends upon the quantity (y) and quality of care produced. Ignoring the problems inherent in such an approach suppose that the quality variable is dependent on the number of inputs (x) used per unit of output.* Further make the natural assumption that output is an inverse function of its price $(y=\rho(Py))$ and that output cannot exceed the capacity of the facility $(\bar{y})$. Then the problem appears

$$\text{Maximize:} \quad \emptyset\left(\frac{x}{\rho(P_y)}, \rho(P_y)\right) \quad \text{w.r.t. } x_1, P_y$$

$$\text{Subject to:} \quad \text{(i)} \quad P_y \cdot \rho(P_y) - P_x x + D \geq 0$$

$$\text{(ii)} \quad \bar{y} - \rho(P_y) \geq 0$$

*The problems stem from the fact that if quality is defined as an input measure then it is directly manipulable by the hospital administration with no necessary increase in patient satisfaction or cure rate etc. This problem is also manifest in hospital cost index construction for use in prospective reimbursement or price regulation schemes.

Assuming operation at less than capacity yields the reduced form necessary conditions below:

$$-\frac{\emptyset_2}{\emptyset_1} = \frac{\rho(P_y^*) \cdot MPR - C}{\rho^3}$$

where

MPR = marginal patient revenue = $\rho + P_y \rho'$

$\bar{C}$ = patient input cost = $P_x \cdot x$

$\emptyset_i$ = partial derivative of $\emptyset$ w.r.t. the i^{th} argument.

Thus the NFP institution whatever the <u>form</u> of the objective function, determines the optimal patient load and "quality" level using the market determined revenue and cost effects.

However, as we have pointed out, the military hospital and the HMO integrated into a prepaid health program have none of these direct market charges (revenue points or centers) with which to assist in the internal resource allocation process.

What is needed then is a decision model which replaces the information not available in this usual fashion.

If we can define the elements and the process by which inputs are transformed into health care of various types then the set of equations describing this situation can serve as the basis for construction of a particular optimization problem once the objective (function) is specified.

In implicit form this says that if the set of ℓ simultaneous equations

$$g^1 (y_1, \ldots, y_n, x_1, \ldots, x_m) = 0$$

$$\vdots$$

$$g^\ell (y_1, \ldots y_n, x_1, \ldots, x_m) = 0$$

where y_i is the i^{th} type of output and x_i is the i^{th} type of input of the production process, describes how the outputs may be produced with given budgets and technical knowledge, then maximization of any given objective function $\emptyset^k(\bar{y},\bar{x})$ yields a set of shadow prices, say λ^i, $i = 1,\ldots,\ell$ in terms of the incremental value of $\emptyset$ associated with a relaxation of the associated constraint.

Clearly then the military hospital administrators could use these shadow prices internally as well as externally. That is, by ordering the λ's they would know, given an increase in their operating or capital budgets where to allocate this increase in order to assure the greatest gains. On the other hand, the shadow prices allow them to quantify beforehand the potential benefits which would accrue if the decision-makers in charge of their various budgets saw fit to increase the flow of funds to the hospital.

The central decision makers could compare the submitted shadow values of the various hospitals and allocate their fixed budget among the competing institutions in order to maximize overall benefits.

These uses of shadow pricing where market values do not exist are well known in the public choice literature (e.g., see [6] and [11]) but do not seem to have been applied or even recognized in the subset of the DOD operations known as the military health care delivery system.

In the remainder of this paper we specify a preliminary attempt at modelling the production process of a military hospital and its analytical utility.

III. THE MODEL - INTRODUCTION

It was determined that the recognized organizational structure of the RMC/HMO was not suitable for the purposes of the present model. However, recognizing the need to retain at least the basic units of the present organization in order to maintain credibility at the operational level, it was decided to reorganize the present units along functional lines.*

The first step was to analyze the general nature of operations at the satellite dispensaries to determine whether there existed similarities allowing simplification of the model. This involved review of the workload distribution at each location, a detailed breakdown of the outpatient visits, and a catalogue of patient distribution by general groups. It was apparent from the diverse nature of the workload and patient distribution that a model treating personnel resources in detail must incorporate each dispensary independently. The travel distance from the hospital to each dispensary is widely variant also and this factor is important in considering partial allocations of central resources to satellite facilities.

Seven levels of activity are defined based on the roles the various units play in providing medical care to patients. At this stage the assignment of units to each defined level is arbitrary, the purpose being to guide construction of the model. Further analysis may require more and/or finer definitions of levels and reassignment of units. It is traditional to consider patient care as either inpatient or

*This procedure is neither a rigorous application of program budgeting technique nor is it entirely satisfactory in the long run since the present units are not all homogeneous in function, however it is adequate in this initial analysis.

outpatient treatment. This distinction is maintained in the model only by the division of patient categories, to be discussed after the formulation of the model. The two levels defining direct patient care activity in the proposed structure appear, from the units listed for each, to maintain this division; however a considerable amount of care for ambulatory inpatients is provided in areas traditionally considered outpatient facilities. To emphasize this the two areas have been named 'primary' and 'secondary' instead of the traditional terms. It is important to properly account for total usage of each area to provide the correct information for decisions on physical resource allocations.

1. Definitions of Functional Levels

a. Primary Treatment - incorporates those areas where physicians offices, examining rooms and clinic facilities are located.

b. Secondary Treatment - areas, not included above, where extensive treatment is conducted. These areas are more specialized in nature and are detached from physicians' offices. Inpatient wards are included here for reasons discussed in the preceding paragraph.

c. Treatment Support - areas included in this level are equipped and designated for specialized treatment procedures or services.

d. Diagnostic Support - especially equipped areas to which patients or specimens are sent for specific analytic procedures.

e. Non-treatment Support - the functions of areas included here may be medical or non-medical in nature but do not involve direct medical care. They provide direct support to medical functions.

f. Medical Administrative Support - these areas perform administrative functions dealing primarily with medical care, as opposed to organizational administration.

g. General Support - the remaining support units in the organization exclusive of those included in Base Support.

h. Base Support - those areas providing support to the Naval Facility per se rather than to the hospital specifically.

2. Proposed Functional Organization

Primary Treatment

allergy	military sick call
cardiology	neuropsychiatry
dental	neurosurgery
dermatology	obstetrics/gynecology
ear-nose-throat	opthamology
emergency room	orthopedics
family practice*	pediatrics
general practice	surgery
internal medicine	urology

* when added

Secondary Treatment

cardiac care unit	operating suite
delivery rooms	nursery
labor rooms	surgical intensive care
medical intensive care	inpatient wards*

* listed by service

Treatment Support

aural-speech therapy	physical therapy
drug rehabilitation	prosthetics lab
occupational therapy	radiation therapy
pharmacy	

Diagnostic Support

EEG	EKG
laboratory	nuclear medicine
radiology (less therapy)	

Non-treatment Support

central sterilizer	medical library
chaplains	medical repair
food service	nursing administration

Medical Administration

admissions	outpatient administration
medical records	patient affairs

General Support

clinical investigation center	preventive medicine unit
data processing	operating services
hospitalman school	supply/fiscal
central administration	

Base Support

housing	security
maintenance/utilities	special services
public works	transportation

3. Notation System

Developing familiarity with the notation of a complex model is difficult even for the experienced analyst. In order to minimize this problem a systematic notation scheme was developed which also serves as an index to variable definitions. This scheme is diagrammed in figure 1.

(e) / (c) / (d) / (a) / (b) . . .

figure 1

The following definitions of the parts of the notation are provided:

(a) Two letters are used to identify the resource; for example, DR indicates physicians. The codes used are defined as they arise in the text of the model.

(b) Up to three subscripts i, j, and k are used to indicate:

i - subclasses of the resource
j - location
k - patient category

(c) A one letter code indicates what quantity is being measured with regard to the resource; for example, ADR indicates available time of physicians. The following codes are used:

A - availability
B - budget
C - personnel constraints
D - demand
D_s - demand defined in submodel
F - physical capacity constraints
M - derived constraints (defined in text)
N - number of personnel
O - overtime or backlog
R - resource vector
R_s - resource variable used in submodel
$ - cost

(d) Computations with subscripted variables often require summation over the range of one or more of the subscripts. One or two letters preceding the resource designator serve to identify the subscript summed over and thus indicate how the remaining subscripts are to be read. This is necessary to avoid confusion in use, where numbers replace letters as subscripts. Absence of this code indicates subscripts are read in order, i.e. i; i,j; or i,j,k. Thus only the following special codes are needed:

I - indicates remaining subscripts are j,k
IJ - indicates remaining subscript is k
IK - indicates remaining subscript is j
J_h - indicates summation over hospital locations
J_d - indicates summation over dispensaries only

(e) A modifier Δ_ℓ indicates an increment of the variable named that is generated separately in a submodel. The values of ℓ are defined in the submodel sections.

The following examples are provided to assist interpretation of the notation. For generality let X denote any resource variable.

$DX_{i,j,k}$	= total demand on subclass i of resource X in location j by all patients in category k
$DX_{i,j}$	= total demand on subclass i of resource X in location j by the sum of all patients
DX_i	= total demand on subclass i of resource X by the sum of all patients in all locations
$DIX_{j,k}$	= total demand on resource X as a whole in location j by the sum of patients in category k
$DIJX_k$	= total demand on resource X as a whole over all locations for all patients in category k
DX	= total demand by the system on resource X
$\Delta_\ell DJ_h IX_k$	= the amount of demand on resource X generated in submodel ℓ over all hospital locations by the sum of patients in category k

4. The Resource Vector

The total resource vector is simply a list of all the system resources whose usage is of interest at a specific point in time. There is a resource subvector for each category of patient defined in the model. These patient categories are discussed in section XI. The purpose of this section is to propose the resource variables for the initial model, define them and outline their measurement. Later sections provide for manipulating the resource vectors to produce cumulative results of analytic interest.

For each patient category the resources used by representative patients of that category must be identified. The initial model uses the average amount of resource consumed per patient in the resource vector. Later studies could use random variables on as many resources as considered pertinent for their purposes, without changing the model structure. Each variable is an aggregate measure of resource usage which means that, for example, if four nurses spend ten minutes each with a patient then forty nurse-minutes are consumed. While the resource vector contains several hundred variables it must be recognized that only a few will be used by a particular patient category. Formulating the vector in general terms provides for ease in understanding and facility in adding or deleting both patient categories and resource variables as desired for later management purposes.

While the model was developed for use at the NRMC, Oakland the discussion in the ensuing sections is general in nature so that other health facilities can adapt it for their own use. For this reason, there are variables defined which may not be pertinent at a given facility. These variables do not affect the formulation of the model and may be simply deleted where appropriate. This being the initial modeling effort, not all resources appear specifically in the model. Those that do not are considered part of fixed costs for the present.

5. Resource Variables - Codes

Subscripts

a. i — subclassifications of primary variables. These are defined separately for each variable and are listed below.

b. j — location codes

01. General practice clinic
02. Emergency room
03. Dermatology - primary
04. Medical Service - primary
05. Neuropsychiatry - primary
06. Obstetrics/gynecology - primary
07. Opthamology - primary
08. Orthopedics - primary
09. Otolaryngology - primary
10. Pediatrics - primary
11. Surgical - primary
12. Urology - primary
13. Neurology - primary

14. Dermatology - secondary
15. Medical service - secondary
16. Neuropsychiatry - secondary
17. Obstetrics/gynecology - secondary
18. Opthamology - secondary
19. Orthopedics - secondary
20. Otolaryngology - secondary

21. Pediatrics - secondary
22. Surgical - secondary
23. Urology - secondary
24. Neurology - secondary
25. Nursery

26. Dispensary - Naval Supply Center, Oakland
27. Dispensary - Alameda
28. Dispensary - Treasure Island
29. Dispensary - Skaggs Island
30. Dispensary - Vallejo
31. Dispensary - Mare Island
32. Dispensary - Moffet Field
33. Dispensary - Concord
34. Dispensary - Stockton

c. k — patient categories (see section X)

<u>Variables</u>

a. $RDR_{i,j,k}$ — physician time

<u>subclassifications</u>

1. Dermatologist
2. General Practitioner
3. General Surgeon
4. Internist
5. Neurologist
6. Neurosurgeon
7. Obstetrician/gynecologist
8. Orthopedic surgeon
9. Pediatrician
10. Plastic surgeon
11. Psychiatrist
12. Psychologist
13. Thoracic surgeon
14. Urologist

b. $RDS_{i,j,k}$ — resident/intern time

<u>subclassifications</u>

1. Internist resident
2. OB/GYN resident
3. Orthopedic resident
4. Pediatrician resident
5. Psychiatrist resident
6. Surgical resident
7. Urologist resident
8. Intern

c. $RNR_{i,j,k}$ — nurse time

<u>subclassifications</u>

1. Registered nurse
2. Licensed nurse
3. Student nurse
4. Nurse's aide

d. $RPM_{i,j,k}$ — paramedic time

<u>subclassifications</u>

1. all paramedic personnel

e. $RMA_{i,j,k}$ — Medical assistant time

<u>subclassifications</u>

1. All medical assistants. Analysis may indicate the desirability of a detailed breakdown.

f. $RMR_{i,j,k}$ — medical record preparation time

<u>subclassifications</u>

1. physician's time
2. processor's time

g. $RLB_{i,j,k}$ — laboratory test units

<u>subclassifications</u>

1. Biochemistry
2. Blood Bank
3. Hematology
4. Microbiology
5. Pathology
6. Urinalysis
7. Morgue

h. $RXR_{i,j,k}$ — X-ray test units

<u>subclassifications</u>

further analysis is required with expert help to designate appropriate subclassifications in this area. In addition to nuclear medicine and special procedures, the common requests should be included separately.

i. $RPH_{i,j,k}$ — pharmacy units issued

<u>subclassifications</u>

further analysis is required with expert help to designate appropriate subclassifications in this area. Broad groups such as anti-biotics should be designated.

j. $ROR_{i,j,k}$ — operating room time

<u>subclassifications</u>

1. General operating room
2. Orthopedic operating room
3. Neurology operating room
4. recovery room

k. $RST_{i,j,k}$ — surgical team time

<u>subclassifications</u>

1. General surgeon
2. Plastic surgeon
3. Thoracic surgeon
4. Orthopedic surgeon
5. neurosurgeon
6. surgical resident
7. operating room technical supervisor
8. operating room team member
9. operating room nurse
10. anesthesiologist
11. anesthetist nurse

l. $RTH_{i,j,k}$ — therapy facility time

<u>subclassifications</u>

1. audio-visual therapy
2. physical therapy
3. occupational therapy
4. radiation therapy

m. $RSF_{i,j,k}$ — special facility time

<u>subclassifications</u>

1. Medical intensive care unit (MICU)
2. Surgical intensive care unit (SICU)
3. Cardiac care unit (CCU)
4. Labor room
5. Delivery room

n. $RFA_{i,j,k}$ - facility time

<u>subclassifications</u>

this variable measures time at locations j and thus there are no subclassifications on i.

o. P_k - the number of patients of category k.

While not a part of the resource vector, this term is defined here for convenience.*

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*Because of the admitedly preliminary nature of this paper, we will not here discuss the full definition and measurement of the resource variables just presented. Those wishing more detail should consult [19], available from the Defense Documentation Center.

IV. THE DEMAND EQUATIONS

The k resource vectors, one for each patient category, contain the basic data relating treatment of an average individual patient to resource consumption. Given a set of patient loads P_k, various quantities of analytic interest can be derived by appropriate mathematical manipulation. The quantities of particular interest in the current study are developed below. The techniques employed are equally suitable for generating other quantities needed by management for a specific study. For simplicity, the equations are illustrated in terms of one resource as an example. In writing out the full model there will be one equation of each type for each resource variable used. In writing the specific equations care must be exercised to ensure the proper range for each subscript in the equation is specified.

Following the exposition of the general demand equations various possible treatments of those variables which are inputs to submodels or which involve personnel in training are discussed.

In all of the quantities defined below the increments of demand added from submodels is excluded. These increments are accounted for in the sections dealing with constraint and cost equations.

1. <u>Demand on a subclass by a patient category, k</u>

a. At a specific location, j:

Multiplying the kth resource vector, R_k, by the number of patients of category k, P_k, has the effect of multiplying every component variable of that vector by P_k. Thus, the amount of dermatologist time required in the primary treatment area by P_k patients of category k is given by:*

(1) $$DDR_{1,12,k} = P_k * RDR_{1,12,k}$$

b. Over all locations:

The demand generated for dermatologist time in the whole system by the P_k patients of category k is found by summing the demand at each location. This is written:[3]

(2) $$JDDR_{1,k} = \sum_j P_k * RDR_{1,j,k}\ , \quad j = 1 - 34$$

c. At the hospital only:

This variation of Equation (2) to generate the demand at the hospital vice the whole system is provided as

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*the symbol * will be used throughout to denote multiplication

a one time example of how to modify the various equations in the model to provide additional information:

(3) $$J_h DDR_{1,k} = \sum_j P_k * RDR_{1,j,k} , \quad j= 1 - 25$$

2. <u>Demand on a subclass by total patient load</u>

a. By location:

This quantity is generated by summing the demand of each patient category on the desired variable. For example, the total demand on dermatologists in the primary treatment area is written:

(4) $$DDR_{1,12} = \sum_k P_k * RDR_{1,12,k} , \quad k= \text{all values}$$

b. Over all locations:

Summing the total demand at each location generates the total demand. Thus the total system demand for dermatologists is written:

(5) $$DDR_1 = \sum_j \sum_k P_k * RDR_{1,j,k} , \quad j= 1 - 34, \; k= \text{all values}$$

3. <u>Demand on a primary variable by a patient category, k</u>

a. By location:

The primary variable demand is found by summing over the subclasses of that variable. Thus, the demand for physicians in the medical service secondary area generated by the number of patients in category k is written:

(6) $$IDDR_{15,k} = \sum_{i} P_k * RDR_{15,k}$$

b. Over all locations:

The systemwide demand on a primary variable by the patients of a category is generated by summing the location demand over all locations. The demand for physicians by the number of patients in category k is written:

(7) $$IJDDR_k = \sum_{i} \sum_{j} P_k * RDR_{i,j,k} , \quad j=1-34, \ i-1-14$$

4. <u>Demand on a primary variable by total patient load</u>

a. By location:

The demand by patient category is summed over all categories defined. Thus, the demand on physicians in, for example, the emergency room is written:

(8) $$IKDDR_2 = \sum_{i} \sum_{k} P_k * RDR_{i,2,k} , \quad i=1-14, \ k=\text{all values}$$

b. Over all locations:

The total amount of a resource required by all patients treated is generated by summing the location demand over all locations and in the case of physicians is written:

(9) $$DDR = \sum_{i} \sum_{j} \sum_{k} P_k * RDR_{i,j,k} , \quad i=1-14, \ j=1-34, \ k=\text{all values}$$

Most of the resource variables dealing with treatment and diagnostic support are treated in the resource vector as inputs to a submodel. There are many possible approaches to using these variables depending on the purpose of the analyst and the computational resources available. Each different approach requires different cost equations and coefficients. Three major variations are discussed here to illustrate the possibilities. The laboratory is used as a representative example.

The decision on how to model these support areas is made primarily on the basis of how important the usage of individual resources at the support level is to the analysis at hand. If the problem does not require a detailed knowledge of how the support resource usage varies it is sufficient to use the general demand equation directly. The cost equation in this case will have coefficients stated in terms of the total cost to operate the support facility. For the laboratory there would be six variables giving the total demand for each of the six types of tests. The cost coefficients would be stated in terms of cost per test. These equations, of the form to be discussed in section IX, would be included with the other cost equations and a submodel would not be necessary.

If the analyst is interested only in one or two resources used in the support structure and is content to lump the rest together as discussed above then the resource vector can be

modified to incorporate these. In the laboratory, for example, if it were of interest only to analyze the demand for pathologists, the physician variable — RDR — could be modified by adding a subclassification 'i=15 — pathologist' and then treating the model as discussed in the first case above. In this case the cost coefficients would be modified by removing all of the costs of employing pathologists. Pathologist cost would be accounted for along with all the other resource costs as discussed below.

In an initial analysis, such as this one, it is usually desirable to incorporate as much detail as possible until the effects of patient load variation on resource usage is understood and then to simplify the model for use by deleting the variables that do not contribute to the analytic effort. This objective is conventiently achieved with the use of submodels because each submodel is independent of the rest and can be modified or deleted altogether without affecting the others. This is essential in maintaining flexibility and minimizing confusion. It has the added benefit of allowing several people to work on an analysis simultaneously and yet independently. The detailed development and discussion of the submodels proposed for this study is contained in section V.

Oakland Naval Hospital is a teaching facility with residencies in several medical specialties, an intern program and assorted schools for Hospital Corps personnel.

One of the major difficulties encountered by past efforts to define the output of health facilities has been in dealing with the dual mission of teaching facilities. Compounding the problem of defining output in terms of patient care is the fact that some of the resources utilized in treating patients are simultaneously receiving benefits in terms of the experience derived from the treatment of those patients. It is not the purpose of this report to propose solutions to this problem, however the model will be used for studying ways to quantify the training benefits separately from the patient care benefits. For this reason it was important to provide appropriate variables in the model for these studies which was done by creating separate variables for personnel in a training status. One question remains to be answered — how to decide between assigning resource demand to the student or the instructor. The answer to this question must depend on the policy of the hospital and further study is required before the specific approach for the NRMC model can be formulated. Two possible approaches are outlined below for illustration using residents as an example.

1. Divide the defined patient categories into groups such as the following:

Group 1: patients are seen by residents, if available

Group 2: patients are seen by a fully qualified physician

Group 3: patients are seen by both residents and fully qualified physicians as a matter of routine

Group 4: patients are seen by a physician, and a resident if available

Group 5: There is no set policy.

The resource variable to be assigned the demand would then be chosen as follows:

Group 1: assigned to the resident
Group 2: assigned to the physician
Group 3: the time demand for each must be estimated
Group 4: treat as group 2 ignoring resident time
Group 5: assign the time to residents and let the constraint on resident time assign the excess to physicians

2. A different approach is to divide the patient load for a given category on a percentage basis determined from historical data or set by a policy decision. Estimate separately the time required for treatment by a resident and by a fully qualified physician. Multiply these estimates by the corresponding fractions and use these values in the resource vector. When multiplied by the total patient load for that category in determining the demand, the correct balance is automatically generated.

Whatever approach used in a particular study it is essential that it be consistently used and well defined so that the effects of whatever assumptions are made can be analyzed.

V. SUBMODELS

This section develops in detail the submodels alluded to in previous sections. The designation R_s has been used for resource variables defined in these submodels because the subscripts are defined differently than in the main model. The distinguishing designator should aid in avoiding the confusion possibly created by this procedure. The first submodel is explained in detail. The discussion of succeeding submodels is more cursory where the explanations in the first apply.

A. LABORATORY SUBMODEL

Subscripts used in this submodel are:

i — laboratory areas as used in main model:

1. Biochemistry
2. Blood bank
3. Hematology
4. Microbiology
5. Pathology (less morgue)
6. Urinalysis
7. Morgue

ℓ — laboratory personnel categories:

1. Pathologist
2. Bacteriologist
3. Medical Technologist
4. Biochemist
5. Pathology resident
6. Technical assistants
7. Medical record processors

1. $R_sPL_{i,\ell}$ — personnel time

a. Definition — This variable accounts for the time demand on personnel of category ℓ per test unit in area i.

b. Measurement — For each area determine the common test procedures performed and the percent of the total

accounted for by each. Determine, for each test, the time increment required for each task in the test procedure. Compute a weighted average time per test for each personnel category.

2. R_sRL_i – process time

a. Definition – the value of this variable is the processing time for the average test in area i.

b. Measurement – For each of the common tests used to compute personnel time, estimate the time that testing facilities are in use, assuming no pauses, utilizing the test procedure normally followed. Where batch testing is the common procedure this time should be the time to process one sample through the batch procedure. The weighted average of these times is used as the time to process the average test.

3. α – the death rate

a. Definition and measurement – the death rate of a hospital is normally expressed as a rate per 1000 inpatients. If data is available, a more accurate measure would be a weighted average of the death rate per patient category. In either case α is expressed as the death rate per inpatient.

4. β_i – batch processing factor

a. Definition and measurement – For each area i this variable is the weighted average number of samples per batch normally run for the common test procedures defined above.

5. <u>γ — the autopsy rate</u>

a. Definition and measurement — the percent of deaths for which autopsies are performed is recorded here.

6. <u>δ_i — adjustment factor</u>

a. Definition and measurement — this variable is an estimate of the percent of the time recorded for process and personnel time which must be performed on every sample, i.e. for which there is no saving due to batch processing.

Using these variables the demand on the resources of the laboratory can be computed. One example of each type demand equation is given for illustration. Different demand quantities can be generated simply by using different demand variables as defined above.

The demand for technical assistants in hematology as the result of total patient load is written:

$$\text{(10)} \qquad \dot{D}_s PL_{3,6} = DLB_3 * R_s PL_{3,6} * \delta_3 + \frac{DLB_3}{\beta_3} * R_s PL_{3,6} * (1 - \delta_3)$$

This equation says that the total demand for technical assistant time in hematology generated by the overall patient load is equal to the number of samples (DLB_3) multiplied by the time per test required for each sample ($R_s PL_{3,6} * \delta_3$) plus the number of batches tested (DLB_3/β_3) multiplied by the time per batch ($R_s PL_{3,6} * (1 - \delta_3)$). In formulating the demand on

other laboratory personnel care must be taken to use the factor δ only where personnel are involved in performing batch testing.

For those personnel working in more than one area the equations must take this into account. For example the time demand for pathologists generated by the total patient load is written:

$$(11) \quad D_sPL_1 = DLB_1 * RPL_{1,5} + (\sum_k P_k) * \alpha * \gamma * RPL_{1,7}$$

where the range of k covers all inpatient categories

This equation says that the total demand for pathologist time generated by the overall patient load is equal to the demand generated in pathology plus the number of autopsies performed multiplied by the time per autopsy.

B. RADIOLOGY SUBMODEL

The manner in which the radiology department is modeled depends on the physical set up of the rooms and equipment. At Oakland Hospital rooms with different capabilities are designated for specific procedures. Thus in addition to the demand placed on personnel and equipment it may be of interest to study the demand on particular areas of the department. A procedure to accomplish this is developed in this submodel. As mentioned before, further study is required to divide the workload of radiology into suitable groups for the study. This submodel is complete except for these groupings.

Subscripts used in this submodel are:

i — X-ray procedures

to be developed

ℓ — radiology personnel categories

1. Radiologist
2. Radiologist resident
3. operating technician
4. processing technician
5. medical record processor

The following variables are defined:

1. $R_sPR_{i,\ell}$ — personnel time

a. Definition — the time demanded of personnel type ℓ to perform procedure i. The same considerations previously discussed in measuring personnel time apply.

2. R_sRR_i — facility time

a. Definition — The time that a radiology facility is unavailable due to procedure i being performed is entered here. If a facility is normally set up for a specific procedure and the set up is changed only when a different procedure is performed then the set up time should be included in the variable. If this is not the case then an estimate of set up time adjusted for the probable number of times performed should be included.

The demand equations for personnel are written exactly as in the laboratory submodel. To generate the demand for special groupings the following example illustrates the procedure. Assume there are 10 procedures defined and three rooms set up as follows: Room 1 handles procedures 1-3; room 2 handles procedures 4-7; and room 3 handles procedures

8-10. Designating the demand on rooms by D_sRM_i, i=1,2,3 the equations would be written:

(12) $$D_sRM_1 = \sum_i (DXR_i * R_sRR_i) , \quad i=1-3$$

(13) $$D_sRM_2 = \sum_i (DXR_i * R_sRR_i) , \quad i=4-7$$

(14) $$D_sRM_3 = \sum_i (DXR_i * R_sRR_i) , \quad i=8-10$$

As in the laboratory submodel different quantities can be generated by changing DXR_i to toher patient category groupings.

C. PHARMACY

No submodel is proposed initially for the pharmacy.

D. PHYSICAL THERAPY SUBMODEL

The submodels for the therapy facilities are slightly different from the previous ones. Since each therapy submodel is identical the procedure will be explained here and only the variables defined for the others.

The following subscript is used:

ℓ — personnel categories

1. physical therapist
2. technical personnel
3. medical record processor

Variables are defined as follows:

1. R_sPT_ℓ — personnel time

a. Definition — the time demand on personnel category ℓ per treatment.

2. e_ℓ — adjustment factor

a. Definition — this factor is chosen so that when multiplied by the time a patient occupies the facility (RTH) the result is the amount of time the personnel of category ℓ spend with the patient. This factor need not be less than one since resource variables measure cumulative demand. For example two technical assistants each spending 90% of a patients occupying time with him would produce a factor e_2=1.8.

The demand for each personnel category is then simply computed as in the following example:

(15) $D_sTH_2 = e_2 * DTH_2$

If there is a wide variance in the time demand on a personnel category by different patient categories then the variables can be modified by adding a subscript m, for example $e_{\ell,m}$. The subscript m would indicate patient groups formed by dividing the patient categories by similar time demands.

E. OCCUPATIONAL THERAPY SUBMODEL

The subscript used in this submodel is:

ℓ — personnel categories

1. occupational therapist
2. technical personnel
3. medical record processor

The variables are denoted:

1. R_sOT_ℓ — personnel time

2. f_ℓ — adjustment factor

F. AUDIO AND SPEECH THERAPY SUBMODEL

The subscript used is:

ℓ — personnel categories

1. audiologist
2. technical assistants
3. medical records processor

The variables are denoted:

1. R_sAT_ℓ — personnel time

2. g_ℓ — adjustment factor

G. RADIATION THERAPY

Radiation therapy, due to the size of the facility is treated as a fixed cost in the initial model.

H. TRAINEE SUBMODEL

Whether or not training is included as a variable in the output function of the model for a particular study, it is necessary to account for the demand placed on personnel in an instructional role by the health care activity of trainees. This submodel, developed specifically for residents and interns, provides a first approximation to this demand and can be directly adapted to other training categories.

The treatment of patients by residents and interns results in a certain amount of consultation with qualified

physicians. Certain specific situations such as rounds in inpatient wards are accounted for in the resource variables as defined in the main model. These time increments are not to be included in estimating the values of variables in this submodel. Since much of the consultation may be handled by the senior residents it was decided to include them in the physician variable. Consultation in the context of this submodel means all forms of assistance, in person or by phone, directly related to the treatment of a specific patient whether provided on request of the trainee or as a matter of physician policy.

The following variable is defined:

1. $h_{i,j,k,\ell}$ – the consultation factor

a. Definition – this variable gives the percentage of the time a resident/intern of subclass ℓ spends treating a patient of category k which represents the consultation demand placed on a physician of subclass i in location j. The subscripts are those defined in the resource vector: i is the subclass of RDR; j is the location code; k is the patient category code defined in section X; and ℓ is the subclass subscript i of RDS.

b. Measurement – using a random sample of patients the estimate of each h is derived as follows:

$$h = \frac{\text{total minutes demand on physicians}}{\text{total treatment time of patients}}$$

The increment of demand on physician time generated from the submodel is then:

$$(16)\qquad \Delta_{\ell}DDR_{i,j,k} = \sum_{\ell} (DDS_{\ell,j,k} * h_{i,j,k,\ell}) \;, \quad \ell=1-8$$

I. SPECIAL FACILITY SUBMODELS

Special facilities as used in this model are specialized inpatient care areas staffed and equipped to more efficiently provide care that can be delivered in regular treatment areas. The resources used, then, are generally the same however the intensity of use differs. The usage of these facilities is further distinguished in that 1) only a percentage of patients in a given category use them, or 2) they are used for only a portion of total treatment time. For this reason both intensive care facilities and delivery rooms are included in the category of special facilities.

The policy at Oakland Hospital is to count a ward bed as occupied for patients in special facilities. This presents problems in the model for the proper accounting of resource usage and special care must be taken not to count resources twice. Two approaches to this problem are suggested. The first estimates the difference in resource demand between the two areas and assigns this difference to users of the special facility. The second simply treats the special facility in the same manner as the main area and ignores the error generated. The first approach is better suited for

areas where patient stay is relatively long, while the second approach should not generate significant error if the stay in the special facility is short and the intensity of resource usage much greater in the special facility.

For each area a variable is needed for later use in capacity constraints. It seems natural for the capacity constraint in inpatient areas to be bed capacity. However, this may not be the case in special facilities. Since specialized equipment is generally needed in these areas the availability of some equipment may be exhausted before the temporary bed capacity of the area is exceeded. Thus, the constraint variable cannot be decided apriori without preliminary analysis in each area. Provision is made for this variable in the submodels without specifying which factor is to be used.

1. Intensive Care Areas

The following resource vector variables may be affected by operation of an intensive care facility:

$$RDR_{i,j,k}\ ,\quad RDS_{i,j,k}\ ,\quad RNR_{i,j,k}\ ,\quad RMA_{k,j,k}\ ,$$

$$RLB_{i,j,k}\ ,\quad RXR_{i,j,k}\ ,\quad RPH_{i,j,k}$$

where i and j are specified as required.

The following notation is used to designate additional resource demands generated in a special facility :

Δ_ℓ — increment generated in special facility ℓ.

ℓ= 2 — medical intensive care
3 — surgical intensive care
4 — cardiac care
5 — labor room

The additional variables defined for the submodel are:

$m_{\ell,k}$ — the percent of patients in category k that use special facility ℓ estimated from historical data.

$LIM_{\ell,k}$ — the limiting factor variable. The variable value is the amount of time a patient in category k uses the limiting equipment of special facility ℓ. The time may be different from $RSF_{i,j,k}$ which will be used for bed capacity constraints and the cost equations. It includes all the time the limiting equipment is unavailable to other patients as the result of being used by a specific patient.

For each general demand equation an increment from these submodels is generated. For example, the addition to demand on a primary variable by a patient category k over all locations — equation (7) — would be written:

$$(17) \qquad \Delta_\ell DIJDR_k = \sum_i \sum_j P_k * m_{\ell,k} * \Delta_\ell RDR_{i,j,k}$$

where ℓ and the ranges of i and j are specified as appropriate. $\Delta_\ell RDR_{i,j,k}$ is the difference between resource usage at a special facility and the corresponding inpatient care area. The product $P_k * m_{\ell,k}$ is the number of patients using the facility.

In addition the demand equations for the limiting equipment are needed and are written:

$$(18) \qquad D_sLIM_{\ell,k} = P_k * m_{\ell,k} * LIM_{\ell,k} \quad , \quad \ell \text{ and } k \text{ specified}$$

Equation (18) is the demand by patient category. The demand over all patients is written:

$$(19) \qquad D_sLIM = \sum_k P_k * m_{\ell,k} * LIM_{\ell,k}$$

2. Delivery Room

The delivery room could be considered a special form of operating room and modeled in the same manner. Unless the initial analysis shows the delivery room area to be a bottleneck, however, it may be analytically more efficient to simply model a weighted average delivery. The weighted average delivery is computed first by patient category considering the delivery times for procedures performed on that category; then by taking the average over patient categories. The personnel times required are computed in the same manner. The delivery room is then modeled similarly to the therapy facilities.

The following variable is defined:

1. n_ℓ — adjustment factor. This factor when multiplied by delivery time yields the demand on personnel category ℓ, where ℓ is defined:

ℓ = 1 — obstetrician/gynecologist
2 — anesthesiologist
3 — OB/GYN resident
4 — registered nurse
5 — licensed nurse
6 — student nurse
7 — nurse's aide
8 — medical assistant

Using Δ_6 to indicate increments of demand generated in the delivery room submodel, the additions to demand are written as in the following example:

(20) $\Delta_6 DDR_7 = \sum_k (P_k * n_1)$, where k is defined over the range of patient categories using the delivery room. If it is not the case that all patients in a category use the delivery room then an additional variable indicating the percent that do is needed and is used as shown in the intensive care submodel, e.g. equations (17) - (19).

VI. PATIENT CATEGORIES

This section presents hospital data and other considerations important in defining patient categories suitable for use in the model. While a patient categorization scheme is outlined, the detailed analysis required for the final list is beyond the scope of this paper.

A. GENERAL CONSIDERATIONS

One of the traditional categorization schemes used in previous models of health facilities groups patient inputs by homogeneity of resources demanded. Such schemes are useful when one objective of the analyst is to minimize the number of categories in order for the model to reside, in its entirety, in a computer. Unfortunately, compactness also limits the flexibility of such models for detailed analyses such as contemplated in the present study. By programming all the necessary computations, properly formatting the output and using the patient load vector and individual resource vectors as independent inputs, there is no need to limit the number of patient categories defined. It is not of great importance for the present purpose that this procedure does not allow application of mathematical programming techniques in a single run of the data.

It is important for the model as formulated that patient categories be relatively homogeneous with respect to medical service providing primary care. It is desirable that

inpatients and outpatients be independent categories to enable separate analysis of the demands placed by each on the various components of the system. It is also desirable that patient categories be made up of diseases or symptoms requiring similar treatment procedures in order to reduce the variance of parameter estimates. Categories should not be so fine, however, that only minute percentages of workload are represented (unless there is only one category for a particular service).

However defined, the parameter estimates for each category should be the weighted average of estimates for each procedure included in the definition. Care should be exercised to record the precise weighting scheme for each category so that sensitivity analysis by disease can be done if desired. A record of the following form would be most useful:

$$\text{CATEGORY ESTIMATE} = \%_1\text{Estimate A} + \%_2\text{Estimate B} + \%_3\text{Estimate C}$$

B. PATIENT DATA — OAKLAND NAVAL HOSPITAL

The initial step in defining patient categories is to determine how the hospital workload is distributed. Included in this procedure is establishing what the workload is. The data recorded on the Medical Service Reports [18] for Calendar Year 1972 along with a data summary for 23376 inpatients treated in Fiscal Year 1973 was used in an analysis of workload distribution.

The following independent categories reported on the Medical Service Report are taken to comprise the workload: Outpatient visits, inpatient visits, limited services, immunizations and physical examinations. The dental department has been disregarded here, as throughout the model, it being considered an independent organization coincidentally located in the hospital building. Included in the list of inpatient visits are physical therapy and occupational therapy visits. It seemed intuitive that these were visits by people included in other inpatient categories and when these visits were subtracted from the total, as shown in Table 11 below, the total inpatient count corresponded closely with the number of inpatient records, allowing for the time difference in the record period. The same consideration led to deleting all anesthesiology visits from the workload of the hospital for analytic purposes. The total workload for the year was then calculated as shown in Table 1 . The distribution of the workload over component categories is shown in Table 2.

The distribution of patients throughout the hospital in 1972 is shown in tables 3, 4, 5, and 6. Table 3 provides the percentage distribution of workload by the categories listed on the Medical Service Report. Although the distribution of workload is not to be equated with the distribution of resource demand under the present definitions, it is interesting to note that three areas — allergy, general practice and opthamology — account for 46.85% of the total

TABLE 1

WORKLOAD CALCULATION

Total outpatients listed	299011
Total inpatients listed	56494
Subtotal	355505
Less physical therapy inpt.	(12855)
	342650
Less occup. therapy inpt.	(6133)
	336517
Total limited services	139182
Total immunizations	30138
Total physicals	4849
	510686
Less anesthesiology	(13915)
TOTAL WORKLOAD	496771

TABLE 2

DISTRIBUTION OF WORKLOAD

	Number	%
Adjusted outpatients	298170	60.02
Adjusted inpatients	24432	4.92
Limited services	139182	28.02
Immunizations	30138	6.06
physicals	4849	0.98
TOTAL WORKLOAD	496771	

workload. Table 4 presents the distribution of workload within each area as a percentage of that area and the distribution by area of all outpatient visits, all inpatient visits and all limited services. Six areas account for 60.11% of outpatient visits; four areas for 67.27% of inpatient visits; and two areas for 88.5% of limited services. Patient categories in these areas should be carefully

formulated to ensure proper analysis of the resource demand generated. As a general principle it is better to define too many categories initially and have to aggregate them, rather than disaggregating a few since a small number of categories with broad definition may conceal important interactions. Table 5 is provided to illustrate the original numbers used in the percentage calculations. Table 6 lists the support services and the number of services performed by each. The '# per pat.' column contains the number of services for each area per outpatient or inpatient found by dividing total area service by the appropriate number from table 2. (Tables 3, 4, 5, and 6 are located at the end of this section for convenience.)

C. SUMMARY OF FY73 INPATIENT ACTIVITY

A data bank of 23376 records for the inpatients treated in FY73 was provided by Oakland Naval Hospital for use in the overall project. This data was reviewed to determine the distribution of patients by medical and surgical categories using the International Classification of Diseases (ICDA) codes and recorded for each patient in the data bank.

The result of this review for the surgical codes is presented in table 7 by general groups of ICDA surgical codes. The actual number in each group is given for perspective and the percentage distribution in each area of the total surgical patients reported is computed. The number reported is the number of times the code appears, not

the number of procedures performed (which is also included in the data bank). The percentage of inpatient figures given in the table is the proportion of the 23376 records, not the figure in table 2. Of the 23376 inpatients recorded, 10010 or 42.8% were subject to surgical procedures. The analysis for patient categorization should include determining whether or not certain medical ICDA codes are highly correlated with specific surgical codes since this information would be useful in formulating homogenous categories. The relative concentration of patients in individual codes is indicated in the following list showing the percent of patients covered by various numbers of codes out of the 110 possible:

# OF CODES	% OF SURGERIES	% OF INPATIENTS
5	30.64	13.12
10	46.01	19.70
15	56.75	24.28
20	65.61	28.06
25	72.27	30.91

The result of the review for medical codes is given along with the list of patient categories proposed. The actual number is given for subgroups within the major headings of the ICDA codes which account for 100 or more patients. The number is also given for individual codes accounting for large numbers of patients within a subgroup. The percentage of inpatients represented by each heading is indicated with the heading. The concentration of patients in codes is indicated below. There are 1100 potential general codes.

# OF CODES	% OF INPATIENTS
5	11.68
10	17.99
20	27.20
25	30.36
35	36.13
50	43.10
75	52.00

D. AGE AND SEX CONSIDERATIONS

A preliminary analysis of the patient data to determine broad variations in length of stay for inpatients revealed interesting results when the data was broken into age, sex and patient status groups. These results are outlined here to indicate the necessity for detailed analysis prior to aggregating estimates of resource demand. Some medical codes have relatively consistent length of stay figures, while in others there is wide variance. In almost all cases the figure for military personnel appears significantly different from other categories. Table 8 presents the data for six medical codes selected to show the various results encountered.

Medical code 650 shows consistency between age groups and is an example of a homogeneous category. Code 626, consisting almost entirely of civilian females, shows variation in length of stay by age. For a category of this type a weighted average should be sufficient for a well-defined category, sensitivity analysis on varying the weightings being used to investigate hypothesized changes in the

numbers of one or more age groups. Code 401 shows complex variation, each grouping having a different length of stay.

Two general observations emerge from considering the data in the examples. The first is that there is generally a difference in length of stay between males and females, even disregarding the longer length of stay for military males. Where males and females are both important in a category either weighted averages can be used or two separate patient categories defined. The decision should be based on the similarity in resource demand, and the likelihood that the mix might change. The second observation is that there are pronounced differences in the length of stay for military personnel over that for civilians. This was noted in every medical code for which enough patients had been treated from both categories to feel the average might be representative. For military personnel, the length of stay does <u>not</u> include time they were assigned to the hospital but were on convalescent leave. The data was adjusted for these days which were recorded in the data bank.

It is not surprising that length of stay for military personnel should be longer. A civilian well enough to walk and provide basic self-care can be assigned to the outpatient department for follow-up treatment while the patient is recuperating at home. Military personnel are expected to be ready to perform duties on return to his command. Therefore the length of stay for military includes recuperation time

and it may also include additional time awaiting transfer that was not spent on leave. Evidence is not available to determine the existence of this latter quantity however it should not be dismissed without investigation since any inaccuracy in the military length of stay seriously distorts the overall average for particular medical codes. In lieu of a complete analysis, it seems reasonable for the initial analysis to use the civilian length of stay as the demand on medical resources and to treat the difference between the civilian and military length of stay as a demand on military resources. The total cost of operating the NRMC would then consist of medical cost and military convenience cost. Once a complete investigation has been completed, a weighted average length of stay per patient category can be computed.

Patients seen for the first time in an outpatient clinic often require more time than those returning for follow-on treatment. Either separate categories can be defined and the patient transformation factor used or weightings can be used to model the appropriate patient mix. The decision in part should be based on the policy of the clinic concerned. Some have special hours for first visits, others take them as they come.

The first few days of treating inpatients generally consume much greater amounts of resource than the latter stages of recuperation. The essential difference in these two stages is the demand placed on diagnostic and treatment support facilities. In static analysis these differences

are unimportant since all demands are averaged together. For dynamic studies it may be beneficial to define separate categories for those cases where there is a pronounced change in resource demand and the length of the recuperative period is significant.

None of these considerations have been taken into account in proposing the patient categories below. This list can be considered as the minimum categories for initial analysis and is meant to provide a starting point for the detailed analysis required for final formulation. It should be remembered that the patient categories input to the model need not be those of interest in the output as long as they are capable of proper aggregation in the model computations.

LIST OF PATIENT CATEGORIES**

OUTPATIENT CATEGORIES

k	CLINIC	HOURS
1	Allergy	27
2	Cardiology	6
3	Electrocardiogram	30
4	Pulmonary Function	37½
5	Pulmonary Tests	37½
6	Dermatology	17½
7	ACNE	2
8	Ear-Nose-Throat	15
9	Audiology and Speech Therapy	40
10	General Practice	96
11	Internal Medicine	16½
12	Hematology	5
13	Endocrinology	1½
14	Diabetic	1½
15	Gastroenterology	7
16	Rheumatology	3
17	Tumor (medicine)	1
18	Chest (medicine)	22
19	Nephrology	4
20	Electroencephalograph	37½
21	Neurosurgery	15
22	Neuropsychiatry	20+
23	General Surgery	6+
24	Proctology	1
25	Plastic Surgery	4
26	Vascular Surgery	2
27	Thoracic Surgery (Bronchoscopy)	4
28	Tumor (surgery)	3+
29	OB/GYN-Prenatal (new)	0
30	OB/GYN-Prenatal (return)	33½
31	OB/GYN-Complicated Pregnancy	1
32	OB/GYN-Postpartun	2½
33	Family Planning	2½
34	Gynecology	23
35	Dysplasia	2
36	Tumor (GYN)	1½
37	PAP Clinic	2½
38	Opthamology	18½
39	Optometry	25
40	Orthopedic	8
41	Orthopedic (pediatrics)	2
42	Pediatrics	16
43	Well Baby	2¼
44	Urology	2
45	Cystoscopies	16
46	IVP	9
47	VCU	6
48	Neurology	12½

** Explanation at end of table

INPATIENT CATEGORIES

k			
	000-136 INFECTIVE AND PARASITIC DISEASE - 3.1 %		
49	000-009	Intestinal Infections - - - -	147
50	050-079	Viral Diseases - - - - - - - - - -	216
		Remainder - - - - - - - - - - -	297
	140-239 NEOPLASMS - 5.7 %		
52	170-174	Bone, Skin and Breast - - - -	98
53	180-189	Genitourinary Organs - - - - - -	137
54	190-199	Other Malignant Neoplasms - -	168
55	210-228	Benign Neoplasms - - - - - - - -	469
		218-Uterine Fibroma (124)	
51		Remainder - - - - - - - - - - -	357
	240-279 ENDOCRINE AND METABOLIC DISEASE - 3.1 %		
57	250-258	Endocrine Glands - - - - - - - -	375
		250-Diabetes (281)	
58	270-279	Metabolic - - - - - - - - - - -	210
		272-Lipid Metabolism (98)	
59		Remainder - - - - - - - - - - -	92
	280-289 BLOOD DISEASE - 1.8 %		
60		Remainder - - - - - - - - - - -	380
	290-315 MENTAL DISORDERS - 6.5 %		
61	290-299	Psychoses - - - - - - - - - - -	178
		295-Schizophrenia (114)	
62	300-309	Non-Psychotic Disorders - - -	1222
		300-Neuroses (151)	
		303-Personality Disorder (509)	
		307-Transient Disturbance (197)	
63		Remainder - - - - - - - - - - -	8
	320-389 NERVOUS SYSTEM AND SENSE ORGANS - 5.2 %		
64	340-349	Central Nervous System - - - -	109
65	350-359	Nerves, Peripheral Ganglia - -	128
66	370-379	Conditions of Eye - - - - - - -	442
		373-Strabismus (156)	
67	380-389	Disease of the Ear - - - - - - -	355
		381-Otitis Media (171)	
68		Remainder - - - - - - - - - - -	84
	390-458 CIRCULATORY SYSTEM DISEASE - 8.9 %		
69	400-404	Hypertension - - - - - - - - - -	346
70	410-414	Ischemic Heart Disease - - - -	563
71	420-429	Other Heart Disease - - - - - -	346
72	440-448	Arteries and Capillaries - - -	186
73	450-458	Veins and Lymphatics - - - - - -	324
74		Remainder - - - - - - - - - - -	137

k			
	460-519 RESPIRATORY SYSTEM - 7.2 %		
75	460-466	Acute Infections - - - - - - - -	118
76	480-486	Pneumonia - - - - - - - - - - -	203
77	490-493	Bronchitis, Emphysema - - - -	196
		493-Asthma (121)	
78	500-508	Upper Respiratory Tract - - -	687
		500-Tonsils and Adenoids (326)	
		504-Deflected Nasal Septum(115)	
79	510-519	Other Diseases - - - - - - - -	334
		Remainder - - - - - - - - - - -	14
	520-577 DIGESTIVE SYSTEM - 8.0 %		
81	520-529	Oral Cavity and Jaw - - - - -	115
82	530-537	Stomach, Duodenum - - - - - - -	281
83	540-543	Appendicitis - - - - - - - - - -	115
84	550-553	Abdominal Hernia - - - - - - - -	391
85	560-569	Intestine, Peritoneum - - - -	390
86	570-577	Liver, Gallbladder - - - - - - -	443
		571-Cirrhosis of liver (100)	
		574-Cholelithiasis (114)	
		Remainder - - - - - - - - - - -	0
	580-629 GENITOURINARY SYSTEM - 8.3 %		
87	590-599	Urinary System - - - - - - - - -	532
88	600-607	Male Genital Organs - - - - - -	272
89	610-616	Breast, Ovary - - - - - - - - -	253
90	620-629	Uterus, Female Genitals - - -	677
		626-Menstruation Disorder(350)	
		Remainder - - - - - - - - - - -	61
	630-678 CHILDBIRTH AND COMPLICATIONS - 7.9 %		
92	630-634	Pregnancy Complications - - -	125
93	640-645	Abortion - - - - - - - - - - - - -	116
94	650-662	Delivery - - - - - - - - - - - - -	1314
		650-Without Complication(527)	
		657-Prolonged Labor (147)	
		658-Perineum Laceration (241)	
95		Remainder - - - - - - - - - - -	128
	680-709 SKIN AND SUBCUTANEOUS TISSUE - 3.1 %		
96	680-686	Infections - - - - - - - - - - -	290
97	690-698	Other Inflammations - - - - - -	136
98	700-709	Other Diseases - - - - - - - - -	232
		Remainder - - - - - - - - - - -	0
	710-738 MUSCULOSKELETAL SYSTEM - 5.0 %		
99	710-718	Arthritis, Rheumatism - - - -	190
		713-Osteoarthritis (102)	
100	720-729	Osteomyelitis - - - - - - - - -	502
		724-Internal Derangement (101)	
		725-Displaced Disk (142)	

k			
101	730-738	Other Diseases - - - - - - - - -	379
		Remainder - - - - - - - - - - -	0

740-759 CONGENITAL ANOMALIES - 2.0 %

102		Remainder - - - - - - - - - - -	426

760-779 PERINATAL MORBIDITY CAUSE - 1.1 %

103		Remainder - - - - - - - - - - -	231

780-796 ILL-DEFINED CONDITIONS - 4.5 %

104	780-789	Symptoms - - - - - - - - - - - - - 785-Abdomen (110)	715
105	790-796	Senility et al. - - - - - - - -	254

800-999 ACCIDENTS - NATURE OF INJURY - 10.6 %

106	800-809	Skull, Spine Fracture - - - -	248
107	810-819	Upper Limb Fracture - - - - - -	215
108	820-829	Lower Limb Fracture - - - - - -	244
109	830-839	Dislocation - - - - - - - - - -	113
110	840-848	Sprains - - - - - - - - - - - - -	141
111	850-854	Intracranial Injury - - - - - - 850-Concussion (105)	151
112	870-879	Head, Neck Laceration - - - -	127
113	880-887	Upper Limb Laceration - - - -	119
114	920-929	Contusion - - - - - - - - - - -	102
115	960-979	Adverse Effect-Medicines - - -	150
116		Remainder - - - - - - - - - - -	662

Y00-Y30 SUPPLEMENTARY CLASSIFICATIONS - 8.0 %

117	Y00-Y13	Exams Without Sickness - - - - Y03-Follow-up Exams (190) Y09-Sterilization (122)	644
118	Y20-Y29	Classification of Liveborn - - Y20-Single, not Immature (998)	1057

Explanation of contents: The hours listed for the outpatient clinics are those that were scheduled per week as listed in the clinic schedule published by the Chief of Outpatient Service on 1 April 1973. One category is defined for each clinic listed. The information accompanying the list of inpatient categories is discussed in the main text on page 120.

TABLE 3. PATIENT DISTRIBUTION

Area	Outpat.	Inpat.	Lim.Svc.	Total
	PERCENT OF HOSPITAL PATIENTS			
Allergy	2.79	.04	14.88	17.71
Cardiology	1.28	1.12		2.40
Chest	.45	.48	.15	1.08
Dermatology	2.32	.17	.01	2.50
Emergency Room	3.91		.10	4.01
Endocrinology	.18			.18
Gastroenterology	.18			.18
General Medicine	2.96	.07	.22	3.25
General Practice	13.08		.69	13.77
General Surgery	1.62	.05		1.67
Gynecology	3.00		.25	3.25
Hematology	.13			.13
Neurology	.49	.05		.54
Neurosurgery	.32	.02		.34
Obstetrics	2.33		.19	2.52
Occup. Therapy	.12			.12
Opthamology	5.00	.44	9.93	15.37
Orthopedics	3.99	.88		4.87
Otolaryngology	4.31	.65		4.96
Pediatrics	5.78		1.15	6.92
Physical Therapy	1.45			1.45
Plastic Surgery	.22	.01		.23
Proctology	.17			.17
Psychiatry	1.70	.65		2.35
Psychology	.17	.16	.44	.77
Thoracic Surgery	.34			.34
Urology	1.67	.09		1.76
Total	60.02	4.92	28.02	92.96

TABLE 4. PATIENT DISTRIBUTION BY AREA AND TYPE OF SERVICE

	% DISTRIBUTION IN AREA			% OF GROUPING BY:		
Area	Outpt	Inpt.	LmSvc	Outpt	Inpt.	LmSvc
Allergy	15.74	.23	84.03	4.64	.79	53.11
Cardiology	53.30	46.70		2.14	22.83	
Chest	41.97	44.12	13.91	.76	9.71	.54
Dermatology	92.65	6.86	.05	3.86	3.48	.04
Emergency Room	97.48		2.56	6.52		.36
Endocrinology	100			.31		
Gastroenterology	100			.30		
General Medicine	90.67	2.39	6.94	4.93	1.58	.81
General Practice	95.00		5.00	21.80		2.46
General Surgery	96.84	3.16		2.70	1.07	
Gynecology	92.10	.14	7.76	5.00	.09	.90
Hematology	100			.22		
Neurology	90.57	9.43		.82	1.05	
Neurosurgery	93.62	6.38		.54	.47	
Obstetrics	92.46		7.54	3.89		.68
Occup. Therapy	100			.21		
Opthamology	32.57	2.89	64.54	8.34	9.02	35.42
Orthopedics	81.91	18.09		6.65	17.92	
Otolaryngology	86.85	13.15		7.18	13.26	
Pediatrics	83.44		16.56	9.62		4.09
Physical Therapy	100			2.42		
Plastic Surgery	95.41	4.52		.38	.22	
Proctology	97.60	2.40		.28	.09	
Psychiatry	72.30	27.70		2.83	13.26	
Psychology	22.63	20.48	56.89	.29	3.23	1.59
Thoracic Surgery	100			.56		
Urology	94.59	5.41		2.78	1.94	
Total	-	-	-	100	100	100

TABLE 5. NUMERICAL PATIENT DISTRIBUTION

Area	Number of Patients: Outpat.	Inpat.	Lim.Svc.	Total
Allergy	13852	193	73929	87974
Cardiology	6367	5378		11945
Chest	2257	2373	748	5378
Dermatology	11498	851	61	12410
Emergency Room	19441	1	503	19945
Endocrinology	925			925
Gastroenterology	914			914
General Medicine	14691	387	1125	16203
General Practice	65021		3424	68445
General Surgery	8041	262		8303
Gynecology	14932	22	1259	16213
Hematology	667			667
Neurology	2458	256		2714
Neurosurgery	1601	109		1710
Obstetrics	11600		946	12546
Occup. Therapy	624			624
Opthamology	24874	2206	49297	76377
Orthopedics	19830	4380		24210
Otolaryngology	21399	3241		24640
Pediatrics	28703		5698	34401
Physical Therapy	7215			7215
Plastic Surgery	1124	54		1178
Proctology	855	21		876
Psychiatry	8441	3233		11674
Psychology	872	789	2192	3853
Thoracic Surgery	1684	2		1686
Urology	8284	474		8758
Total	298170	24432	139182	461784

TABLE 6. WORKLOAD OF ADJUNCT SERVICES

Category	Outpatients			Inpatients			Total
	Number	# per pat.	% of total	Number	# per pat.	% of total	Number
Lab Tests	1091496	3.66	57.0	821719	33.6	43.0	1913215
Pharmacy Units	344270	1.15	74.0	120380	4.93	26.0	463650
Pulmonary Studies	406	0.0014	58.7	285	0.0116	41.3	691
X-Ray Exposures	157217	0.527	65.1	84149	3.44	34.9	241366
Audiograms	4300	0.0144	92.8	334	0.0136	7.2	4664
Anesthesiology	841	0.0028	6.0	13074	0.533	94.0	13915
Dialysis				333	0.0136	100	333
Cobalt/Cesium Trtmt	1790	0.006	59.3	1227	0.0502	40.7	3017
EEG	713	0.0025	68.9	321	0.0132	31.1	1034
ECG	6699	0.0224	53.5	5822	0.238	46.5	12521
Fluoroscopic Exams	3057	0.0119	57.2	2287	0.0936	42.8	5344
Radioisotope Studies	6747	0.0226	69.5	2963	0.1212	30.5	9710
Radioisotope Therapy	9	-	37.5	15	-	62.5	24
Other Deep Therapy	76	-	96.2	3	-	3.8	79
Physical Therapy				12855			12855
Occupational Therapy				6133			6133

TABLE 7. DISTRIBUTION OF SURGICAL PATIENTS

GROUP	AREA OF SURGERY	NUMBER	% OF SURGERY	% OF INPATIENT
01-05	Neurosurgery	202	2.0	.86
06-14	Opthamology	355	3.5	1.52
16-21	Otolaryngology	887	8.9	3.80
22-23	Thyroid and Adrenals	35	.3	.15
24-30	Vascular and Cardiac	161	1.6	.69
32-35	Thoracic	133	1.3	.57
38-48	Abdominal	1047	10.5	4.98
50-52	Proctology	232	2.3	.98
54-61	Urology	451	4.5	1.93
65	Breast Surgery	84	.8	.36
67-72	Gynecology	1049	10.5	4.48
74-78	Obstetrics	2379	23.8	10.20
80-90	Orthopedics	1145	11.5	4.90
92-94	Plastic Surgery	534	5.3	2.28
95-98	Oral, Maxillofacial	103	1.0	.44
99	Dental	40	.4	.17
A1-A2	Biopsy	418	4.2	1.79
A4-A5	Diagnostic Endoscopy	516	5.2	2.25
A8-A9	Diagnostic Radiography	239	2.4	1.01
	Total	10010	100	42.86

TABLE 8. EXAMPLES OF INPATIENT LENGTH OF STAY DISTRIBUTION

			Military	Civilian	10-18	18-40	40-55	>55
CODE 301 COUNT=509 LOS=23.2 days								
	MALE	LOS	23.1	4.5	22.9	23.1	-	-
		COUNT	471	2	98	373	-	-
	FEMALE	LOS	43.4	15.7	35.8	26.5	-	-
		COUNT	14	22	4	28	-	-
CODE 303 COUNT=207 LOS=30.3 days								
	MALE	LOS	40.2	13.0	16.3	40.4	16.1	15.2
		COUNT	132	57	7	124	44	14
	FEMALE	LOS	-	13.0	-	-	13.4	-
		COUNT	-	18	-	-	11	-
CODE 401 COUNT=320 LOS=14.2 days								
	MALE	LOS	35.5	11.8	-	30.0	21.1	9.6
		COUNT	57	102	-	42	72	44
	FEMALE	LOS	-	8.2	-	8.5	7.4	9.0
		COUNT	-	161	-	35	61	61
CODE 500 COUNT=326 LOS=4.6 days								
	MALE	LOS	11.0	2.1	4.6	10.7	-	-
		COUNT	90	97	30	82	-	-
	FEMALE	LOS	-	2.1	2.0	2.9	-	-
		COUNT	-	133	42	38	-	-
CODE 626 COUNT=350 LOS=4.0 days								
	FEMALE	LOS	17.5	3.4	-	5.3	3.1	2.6
		COUNT	15	335		146	168	30
CODE 650 COUNT=527 LOS=3.6 days								
	FEMALE	LOS	-	3.6	3.8	3.6	-	-
		COUNT	-	526	43	479	-	-

TABLE 9. DISTRIBUTION OF PATIENTS BY PERSONAL STATUS

	OUTPATIENTS				INPATIENTS				TOTAL	
Category	Number	% of pat.	% of outpt	% of ctgy	Number	% of pat.	% of outpt	% of ctgy	Number	% of pat.
Active Duty	47793	14.8	16.03	78.8	12854	3.98	52.87	21.2	60647	18.78
Dependent	103900	32.2	34.85	97.5	2666	.85	10.89	2.5	106566	33.05
Retired	48024	14.9	16.10	91.2	4640	1.45	18.96	8.8	52664	16.35
Dependent	93956	29.1	31.51	96.0	4052	1.25	16.36	4.0	98008	30.35
Other	4497	1.4	1.51	95.2	220	.07	.88	4.8	4717	1.47
Totals	298170	92.4	-	-	24432	7.60	-	-	322602	-

VII. CONCLUSION

We have presented a detailed analytical look at the components and considerations involved in constructing an integrated production function for a military HMO. We have specified a categorization of the resources (inputs) involved, a methodology for measuring demands on this vector, submodels of ancillary service sectors through the use of submodels, and a look at the problems of constructing patient categories by utilizing patient census data.

The discussion and constructions have been disaggregated by design in hopes that fewer of what are considered to be the crucial variables by the operational personnel, would be ignored as compared with previous models.

We have not "written out" the model, or the constraint sets into which it must be integrated, we have not considered the dynamic character which it may be necessary to build in, etc. -- we have left much unsaid! This was due to the fact that this was not meant as a definitive study, or even as a finished "paper" (in the usual sense). Rather we hope that it will generate further work, by us and others, which will result in a model which can be used as discussed in the initial sections. So if as a result of working through the present version you have become dissatisfied and resolved to correct what you perceive as this paper's failings, we have accomplished one of our goals.

We hope that subsequent versions of this model, whether of our doing or from others will provide the necessary analytical apparatus to assist in better resource allocation in the military health care delivery system.

REFERENCES

[1] Baligh, H. H. and D. J. Laughhunn, "An Economic and Linear Model of the Hospital," Health Services Research, 4, #4, 1969, pp. 293-303.

[2] Block, Michael and David Whipple, "A Proposal to Develop A Hospital Cost Index," Mineo, Naval Postgraduate School, Sept 1974.

[3] Cohen, Harold A., "Hospital Cost Curves with Emphasis on Measuring Patient Care Output," in Empirical Studies in Health Economics, H. E. Klarman, ed., pp. 279-293.

[4] Dusansky, R. and P. J. Kalman, "Toward An Economic Model of the Teaching Hospital," Journal of Economic Theory, 7, No. 2, pp. 210-223.

[5] Feldstein, Martin, Economic Analysis For Health Service Efficiency, Chicago, Markham, 1968.

[6] Hitch, C. J. and R. N. McKean, The Economics of Defense in the Nuclear Age, RAND, Santa Monica, 1960.

[7] Kovner, Joel, "A Production Function for Outpatient Medical Facilities," unpublished Ph.D. thesis, UCLA, 1968.

[8] Lave, Judith R., and Lester B. Lave, "Hospital Cost Functions," American Economic Review, LX, No. 3, pp. 379-395.

[9] Lee, Maw Lin, "A Conspicuous Production Theory of Hospital Behavior," Southern Economic Journal, 38:48-58, (July 1971).

[10] Lee, Maw Lin, and Richard L. Wallace, "Problems in Estimating Multiproduct Cost Functions: An Application to Hospitals," Western Economic Journal, XI, No. 3, pp. 350-363.

[11] Margolis, Julius, "Shadow Prices for Incorrect or Nonexistent Market Values," in Public Expenditure and Policy Analysis, Haveman, Robert H. and Julius Margolis, Eds. Chicago, Markham, 1971.

[12] Newhouse, Joseph P., "Toward A Theory of Non-profit Institutions: An Economic Model of a Hospital," American Economic Review, 60:64-74 (March, 1970).

[13] Newhouse, Joseph P. and Vincent Taylor, "The Subsidy Problem in Hospital Insurance: A Proposal," Journal of Business, October 1970, pp. 452-56.

[14] Pauly, Mark and Michael Redisch, "The Not-For-Profit Hospital as A Physician's Cooperative," American Economic Review, 63: 87-100 (March 1973).

[15] Pointer, Dennis D., James D. Bentley, and Robert L. White, "Ambulatory Care Cost Functions in Naval Outpatient Departments: An Empirical Model," Research paper No. 10, Naval School of Health Care Administration, Bethesda, Md. Dec. 1973.

[16] Reinhardt, U. E., "Manpower Substitution and Productivity in Medical Practice: Review of Research," Health Services Research, Vol. 8, No. 3, (Fall 1973).

[17] Taylor, Vincent, "The Price of Hospital Care," RAND Document # P-4090, May 1969.

[18] U.S. Naval Hospital Oakland Report 6300-1, Medical Services Report, to Navy Bureau of Medicine monthly on NAVMED form 1454.

[19] VanWinkle, P., "Regional Medical Centers: A Model For Analysis and Management," M.S. Thesis in O.R., Naval Postgraduate School, Monterey, California.

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